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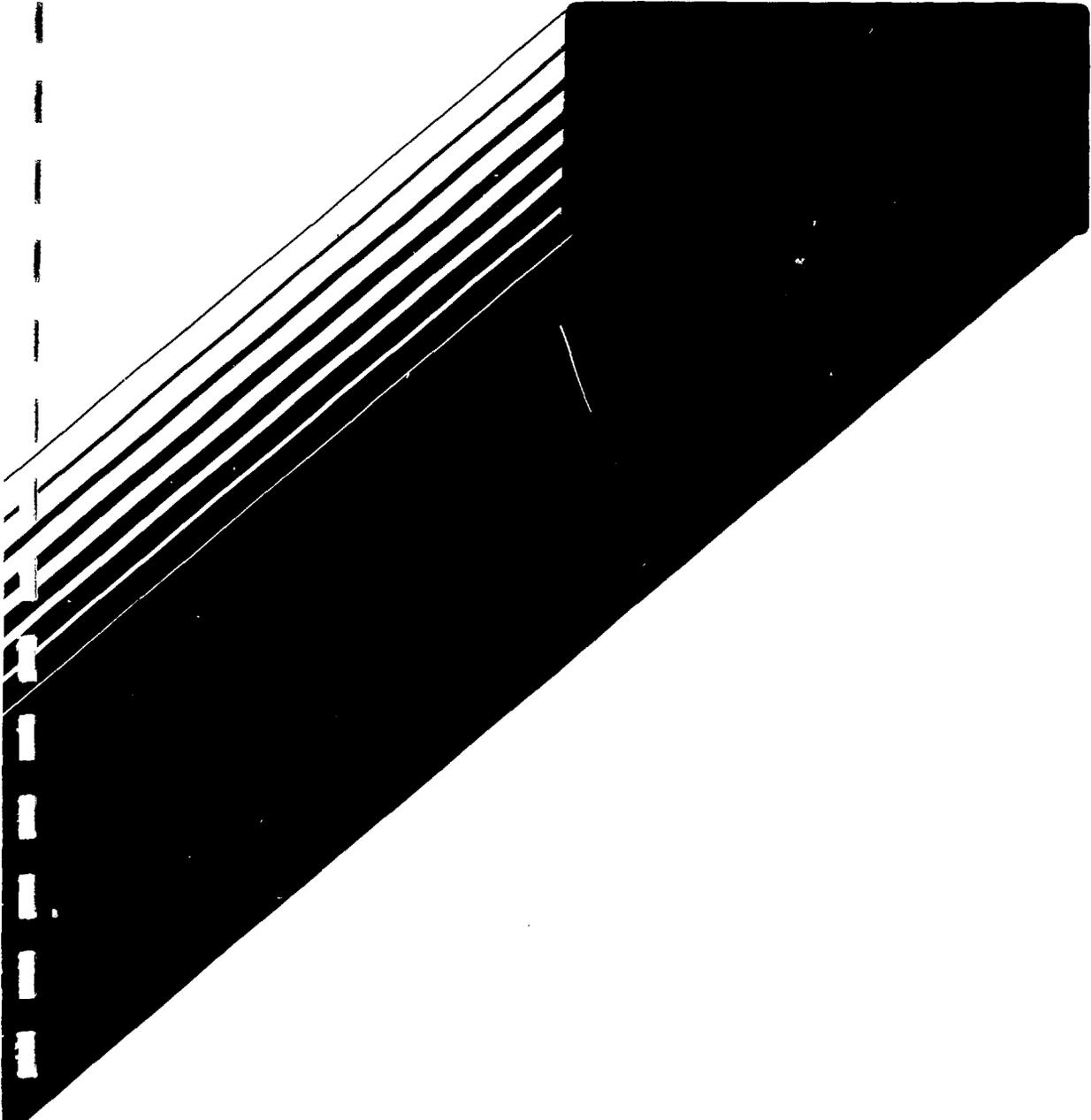
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P.O. Box 1046  
Ottawa, Canada  
K1P 5S9

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Ottawa, Canada  
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ENVIRONMENTAL IMPACT OF URANIUM  
MINING AND MILLING - A CANADIAN  
EXPERIENCE

by

A.B. Dory

Atomic Energy Control Board  
Ottawa, Canada

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MINING AND MILLING - A CANADIAN  
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**Aladar B. Dory, P. Eng., Manager, Uranium Mines  
Division, Atomic Energy Control Board**

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**ABSTRACT**

The author introduces the subject with an overview of the regulatory requirements and philosophy applied to uranium mines and mills. The special attention given to tailings management is highlighted, and a discussion of the basic environmental concerns is concluded with an itemizing of the main tasks facing the AECB. The extent of the environmental impact of uranium mining, milling and waste management is illustrated with specific details pertaining to mines in the Elliot Lake area. The author concludes that the impact on the ground and surface water system is not alarming, and the impact on air quality is not significant beyond a few hundred metres from the mining facilities. The publicly perceived impact is discussed, followed by a rationale for the continued licensing of new uranium mining operations complete with tailings management facilities.

**RÉSUMÉ**

L'auteur aborde son sujet par un aperçu des exigences et des principes de la réglementation appliqués aux mines et aux usines de concentration d'uranium. Il attire particulièrement l'attention sur la gestion des résidus miniers et il termine son étude des questions fondamentales sur l'environnement en énumérant les principales tâches qui attendent la CCEA. Des détails particuliers aux mines de la région d'Elliot Lake illustrent les conséquences de l'extraction minière et de la concentration de l'uranium, de même que la gestion de ses résidus miniers. Il en conclut que les répercussions sur les réseaux d'eaux souterraines et superficielles ne sont pas alarmantes et que celles sur la qualité de l'air ne sont pas importantes au delà d'une centaine de mètres des installations minières. Il aborde aussi le sujet des répercussions du point de vue du public et il établit le bien-fondé d'une réglementation continue des opérations des nouvelles mines d'uranium qui doivent être doublées d'installations de gestion des résidus miniers.

## ENVIRONMENTAL IMPACT OF URANIUM MINING AND MILLING - A CANADIAN EXPERIENCE

It is difficult to provide an assessment of a topic as complex as environmental impacts of uranium mining and milling. The following is therefore only a very sketchy outline of the basic regulatory approaches used in Canada for their minimization.

### A. REGULATORY REQUIREMENTS AND PHILOSOPHY

In the 1950's, when uranium mining and milling first began in Canada on a large scale, tailings storage was handled in the same manner as tailings resulting from all other mining and milling operations. Retention structures (dams) were often built from the coarse fraction of cycloned tailings. Engineering of these dams was minimal and addressed rather short-term stability. Quality control of the actual construction was minimal. Failures of these dams have occurred, resulting in releases of tailings into the environment. Sometimes the waste or tailings material used for the construction of tailings dams had strong acid-generating potential. This, in turn, resulted in acidic seepages with a detrimental effect on the downstream aquatic environment.

As a consequence, the often debated "destruction" of the Serpent River system due to uranium mining in Elliot Lake, Ontario, arose not so much from contamination by radionuclides (e.g. radium-226) as is frequently claimed, but from acidic seepages from the tailings and tailing dams in the watershed area.

As a result of public perception of the level of hazards associated with all aspects of the nuclear industry, uranium mill tailings are now controlled much more rigorously than other tailings, even though their environmental hazards are generally of the same order of magnitude.

The effects of past tailings management practices unfortunately resulted in loss of credibility for the industry and the regulatory process in the eyes of the public. The restoration of this credibility is one of the most important long-term goals of the industry and regulatory agencies.

The Atomic Energy Control Board (AECB) currently requires that tailings management facilities be sited, designed, constructed and operated in a manner resulting in the exposures of workers and public to radioactive and other contaminants which are:

- 1) as low as reasonably achievable, social and economic factors being taken into account, and below the regulatory limits for releases and exposures; and
- 2) below the levels which might be set for a particular facility as a result of site specific conditions.

Adherence to the AECB's requirements for tailings management facilities will result in an operation which meets the above criteria. Upon cessation of operations it provides a good base on which to implement measures to meet the required standards for the post-operational phase. Authorities believe that with the implementation of additional measures currently being

investigated, uranium tailings will meet the criteria of "disposal" in the long term. The term "disposal" means a "walk-away" situation, where the facility is so constructed that the environment is protected from unacceptable releases of contaminants without the need for constant surveillance or corrective human intervention. In reality, the totally "walk-away" situation may not be achieved, and some limitation of land-use may have to be maintained.

The use of new technology coupled with appropriate site selection, quality construction and good operating procedures, can ensure that the impact on health, safety and on the environment will be acceptably low over the period of operation. Further, the methods of retention should be compatible with shut-down procedures, namely chemical and physical stabilization of the tailings and the retention structures which will ensure that any releases to the environment and radiological exposures of man will continue to be within the requirements.

Some concern exists that man-made retention structures (dams) could be susceptible to failures following an extended period of neglect. To minimize the occurrence of these failures, present requirements aim to make the tailings management facilities less reliant on care and surveillance. The dams are required to be "impermeable" to minimize seepage. The impermeability should preferably be achieved by using natural rather than synthetic materials.

In the long term, natural erosion forces, whether resulting in a gradual or sudden transfer of materials, will almost certainly lead to eventual integration of the wastes with the environment. The resulting impact is impossible to predict with certainty but one should not jump to the conclusion that the impact will be catastrophic or even of substantial concern. Innovative methods of tailings placement with good dam design and shut-down procedures can alleviate the concern for catastrophic dam failure. In the absence of a cataclysmic natural event such as glaciation, the integration of the wastes with the environment is likely to be gradual. Should such a natural event occur, the consequences due to the wastes are likely to be secondary to those arising from the event itself.

The radium in the tailings currently emplaced will remain for many thousands of years, and the ensuing radon gas emissions are likely to render closed-out sites unacceptable for the construction of dwellings and for subsequent habitation. Thus in the long term, in the absence of adequate controls to limit public access and land use, people could be subjected to unexpected radiation exposure. Removal of radium and other contaminants from the mill tailings is being considered and investigated as a possible solution to the long-term problems posed by uranium tailings. Whether the tailings could be stripped of radium to the extent that long-term restrictions on land could be avoided is as yet uncertain. The possibility does exist that land-use restrictions will be necessary and will be enforced throughout that period in which institutional controls are predictable.

The AECB considers the health and safety of workers and members of the public to be of primary concern in the assessment of any proposed mining practice. Of great importance also is the influence these mining practices may have on waste streams, subsequent waste management and, consequently, the environment.

Some of the main activities of the AECB staff at the present concentrate on

the following tasks:

- a) development of specific regulations on radiological health and safety and related matters for uranium mine-mill and tailings management facilities;
- b) development of limits for radioactive contaminants. The establishment of release limits for total Radium-226 is currently underway;
- c) development of guidelines for standardization of measuring techniques for various radionuclides in the atmosphere and in liquid effluents;
- d) updating of the Board's requirements as formulated in the licensing guides, to keep these in line with new developments;
- e) continued encouragement of the industry to lead and participate in research and development programs intended to further optimize present operating practices and to resolve the long-term concerns associated with tailings management;
- f) further development of requirements for measures leading to gradual transformation of mill-tailings management to "disposal". Close-out criteria for uranium mill tailings have been drafted (1), and they are being discussed with the appropriate federal and provincial regulatory agencies, industry and the public;
- g) increased participation in public hearings on proposed nuclear facilities.

One important, basic philosophical difference in the Canadian approach to the regulation of the nuclear industry, in contrast to other jurisdictions, is the AECB's strong commitment to encouraging maximum self-regulation of the industry. The application of this principle results in increased responsibility and accountability for industry management.

## B. ENVIRONMENTAL IMPACT OF URANIUM MINING AND MILLING

To illustrate the extent of the environmental impact of uranium mining, milling and waste management, let us look at the mines in the Elliot Lake area of Ontario. This choice is influenced by the international publicity given to this mining area mainly when the negative aspects of uranium mining are illustrated.

Mining in this area started in the early 1950's when the regulatory requirements did not yet treat uranium mining in a different way from other types of mining. As a result, the facilities were developed in a manner which was far short of present regulatory requirements. The environmental impact was particularly worsened by a significant content of sulphides in the ore, resulting in highly acidic effluents from the tailings.

For the purpose of the impact assessment, the radionuclides of main concern are Radium-226 ( $^{226}\text{Ra}$ ) in aquatic releases, and Radon-222 ( $^{222}\text{Rn}$ ), the decay product of  $^{226}\text{Ra}$  in the Uranium decay chain for airborne releases. Radon in turn decays through Polonium 218 ( $^{218}\text{Po}$ -Radium A), Lead 214 ( $^{214}\text{Pb}$ -Radium B), Bismuth 214 ( $^{214}\text{Bi}$ -Radium C) and Polonium 214 ( $^{214}\text{Po}$ -Radium C'), to lead 210 ( $^{210}\text{Pb}$ -Radium D).

## 1. Impact on Ground and Surface Water System

The impact of the mines on the ground water is believed to be minimal and very localized. This is an observation which cannot be generalized. The Elliot Lake mines are all underground, relatively deep mines and the geology of the area is such that one cannot really speak of a regional ground water system. However, mines in other areas with different geological conditions might have a more pronounced impact on ground water. This is particularly obvious when the impact of larger, open pit mines is examined. For example, the planned open pit mine at Key Lake in Saskatchewan will require an intentional lowering of the water table which will significantly lower the ground water level to a distance of several kilometers from the mine. Hence, the ground and surface water effect might be quite significant in some cases, but it is temporary and when mining ceases the ground water table will soon return to its original level.

The impact of tailings management facilities on ground water elevation will also depend on the design of the retention structures. Limited information exists as to the quality and quantity of seepages from a still-operating or dormant tailings facility. It is obvious that during operations, the quality and quantity of seepage is influenced by the permeability of the tailings basin and the design of the system.

Research and modelling work undertaken during Ontario's Environmental Assessment Board hearings on the expansion of uranium mining in Elliot Lake<sup>(2)</sup> has indicated that with minimal close-out measures the seepage from Elliot Lake tailings will carry about 1.5 - 1.85 Becquerel\* per litre (Bq/L) of <sup>226</sup>Ra. This concentration of <sup>226</sup>Ra in the seepage should not have a significant impact on ground water quality provided proper close-out measures minimize the quantity of the seepage. The quantity will depend on the effectiveness of measures to facilitate a speedy run-off of precipitation from the tailings without ponding causing significant percolation through the tailings. However, the chemical composition of the ore-tailings might result in more significant impacts (acid, heavy metals and other chemicals).

Observations at one dormant tailings area failed to indicate any movement of the <sup>226</sup>Ra plume in the local ground water system since the early 1960's. At this facility the tailings were left in a natural lake with no close-out measures implemented when the operations ceased.

More information is available on the amount of <sup>226</sup>Ra released in the effluents to the surface water system. For example, there are annual reports<sup>(3)</sup> indicating the amount of <sup>226</sup>Ra released from Ontario uranium mines into the Great Lakes watershed. The releases from the facilities of the Elliot Lake area are the most significant. The latest available data indicate that there were about  $4 \times 10^{10}$  Bq of total <sup>226</sup>Ra (about  $2.7 \times 10^{10}$  Bq as dissolved\*\*) released into the Serpent River in 1979 from facilities in the Elliot Lake area. Since there is no control in place after the effluent leaves an individual facility, one must make the conservative assumption that eventually the whole amount of <sup>226</sup>Ra released would likely become dissolved and available for entering the food chain. Furthermore, the sulphuric acid originally

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\* 1 Becquerel (Bq) = 1 disintegration per second

\*\* Dissolved <sup>226</sup>Ra in this case is defined as <sup>226</sup>Ra passing through a 1.2 micron filter.

generated from the sulphides in the tailings and entering the Serpent River system resulted in the whole system becoming uninhabitable for fish. Chemical treatment of the effluents over a period of several years has resulted in the gradual decrease of  $^{226}\text{Ra}$  and increase of pH, and the gradual return of fish. The present concentration of  $^{226}\text{Ra}$  in the Serpent River at the inflow to Lake Huron varies between 0.04 - 0.33 Bq/L. The average concentration of  $^{226}\text{Ra}$  in the fish observed is  $0.26 \times 10^{-2}$  Bq/g. The Canadian recommended limits for  $^{226}\text{Ra}$  in drinking water are 1 Bq/L for a maximum acceptable concentration and 0.1 Bq/L as a target concentration<sup>(4)</sup>.

In light of national guidelines and the recommendations of the International Commission for Radiological Protection (ICRP) dealing with  $^{226}\text{Ra}$  levels in drinking water, the impact of releases from uranium mine-mill and tailings management facilities is not alarming. On the other hand, since there is no scientifically proven threshold to the health effects of radiation, concerted efforts are continuing to reduce these releases to levels as low as reasonably achievable, economic and social factors being taken into consideration (the ALARA principle).

## 2. Impact on Air Quality

The impact of uranium mine-mill facilities on air quality results from mine exhausts, open pits, mill ventilation exhausts and emissions from the tailings masses. For the purpose of this presentation, we will deal only with  $^{222}\text{Rn}$  and its daughters since the releases of non-radioactive contaminants either from the mine-mill exhaust or the tailings are not unique to uranium mining.

Contamination resulting from long-lived radionuclides in the airborne dust has not yet been studied extensively in Canada; therefore, it cannot be assessed thoroughly at this time. Results of limited surveys in the Elliot Lake area, however, analysed for gross alpha, gross beta,  $^{226}\text{Ra}$  and uranium indicated that the majority of samples were in most cases below the detection limits for long-lived radionuclides, and the maximum values were only slightly above the detection limit. Measurements of total suspended particulate matter at one townsite in the Elliot Lake area in close proximity to dormant tailings for the years 1977 to 1980 were as follows:

<u>Annual Geometric Mean</u> ( $\mu\text{g}/\text{m}^3$ )				<u>Maximum Reading</u> ( $\mu\text{g}/\text{M}^3$ )				<u>Air Quality Criteria</u> (Ontario - $\mu\text{g}/\text{m}^3$ )	
1977	1978	1979	1980*	1977	1978	1979	1980*	24 hrs.	Annual Geom. Mean
16	15	20	23	67	108	64	82	60	120

\* 1980 data to September only

There is one main feature common to all Canadian tailings facilities which makes them different from those in the United States: the Canadian tailings are saturated with water. This is obviously the main reason that the problems of radon/radon daughter emissions from the tailings are far less serious in Canada than they are in the U.S. Water saturated tailings dramatically slow down the radon percolation rate and experience indicates that only radon generated in the top 10-20 centimeters of the deposited tailings reach the surface.

Extensive measurements of radon daughter concentrations were taken in and around Elliot Lake in 1979 and 1980. The following is a summary of the results:

Location (see Figure 1)	Radon Daughter Concentrations in Working Levels (WL)*		
	Average	Minimum	Maximum
1) About 60 metres between two exhaust stacks	0.0660	0.0010	0.4740
2) 300 metres from exhaust shaft	0.0080	0.0000	0.1110
3) 400 metres from exhaust shaft	0.0012	0.0010	0.0020
4) 1500 metres from exhaust shafts	0.0010	0.0000	0.0030
5) 100 metres from an operating tailings facility	0.0028	0.0000	0.0038
6) A townsite 600 metres from dormant tailings facility	0.0024	0.0008	0.0059
7) A townsite between exhaust shafts, mill exhaust and tailings, minimum distance 1000 metres	0.0071	0.0006	0.0150
8) Elliot Lake Municipal Building - no evident source of radon daughters within 2000 m.	0.0008	0.0003	0.0012

For Comparison:

City of New York, U.S.A.                      0.0007<sup>(5)</sup>                      -                      -

The above indicates that the impact, although significant in close proximity to the source, quickly diminishes within a few hundred metres. For radon abatement purposes there is little flexibility in measures to reduce exhaust from the mine or mill since the protection of the health of workers demands speedy removal of radon daughters from work places. However, measures could be implemented to reduce radon and radon daughter emissions from tailings. It is reasonable to assume that these measures would also reduce gamma radiation fields over and in the vicinity of the tailings, which at present, with no covering, are about three times the natural background in the area.

### 3. Perceived Impact

Mistakes committed in the past and the traditional reluctance of mining companies to talk openly to the public have resulted in a loss of credibility of the uranium mining industry and indeed the whole of the nuclear industry. The general population is subjected to well-publicized views of critics of the nuclear industry which focus on the mistakes of the past without the benefit of facts from the other side of the issue. This naturally results in a biased picture of the industry. Furthermore, as a consequence of the nuclear industry's development from a tool of mass destruction, the health hazards associated with radiation are generally overstated. Society is by and large willing to accept considerable risks (voluntary or involuntary) attending every day life, but is not willing to readily accept radiation risks associated with the nuclear industry even though they are lower by one or two orders of magnitude. A long and difficult process toward

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\* Working Level (WL) = unit of radon daughter concentration  
1 WL =  $2.08 \times 10^{-5}$  Jm<sup>-3</sup>

developing complete openness of the industry and the regulatory agencies, giving the public total and true information, is therefore necessary to regain public confidence and the acceptance of uranium mining and of the entire nuclear industry.

### C. CONCLUSION

The main responsibility of the AECB is to ensure that any nuclear facility which is to be developed meets the regulatory requirements. In this regard, the AECB is now involved from the early planning stages of a mine-mill facility. As a result, new facilities (including tailings management) are designed and developed to a much higher standard than previously.

New criteria regarding the quality of a site and retention structures, as well as technical specifications have been developed. Present technology and practices are sufficiently advanced to ensure the safe operation of uranium tailings management facilities in the present, and with minimal effort, as far into the future as institutional controls may be reasonably assured. There are still unanswered concerns for the longer term and these concerns are being addressed by the industry and government. Our confidence that these concerns can and will be resolved within the foreseeable future is the main justification for allowing new tailings facilities to be developed.

## REFERENCES

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5. Based on measurements in 1973-1974 - Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, 1977 Report to the General Assembly, with Annexes, (UNSCEAR 1977), United Nations, New York, 1977.

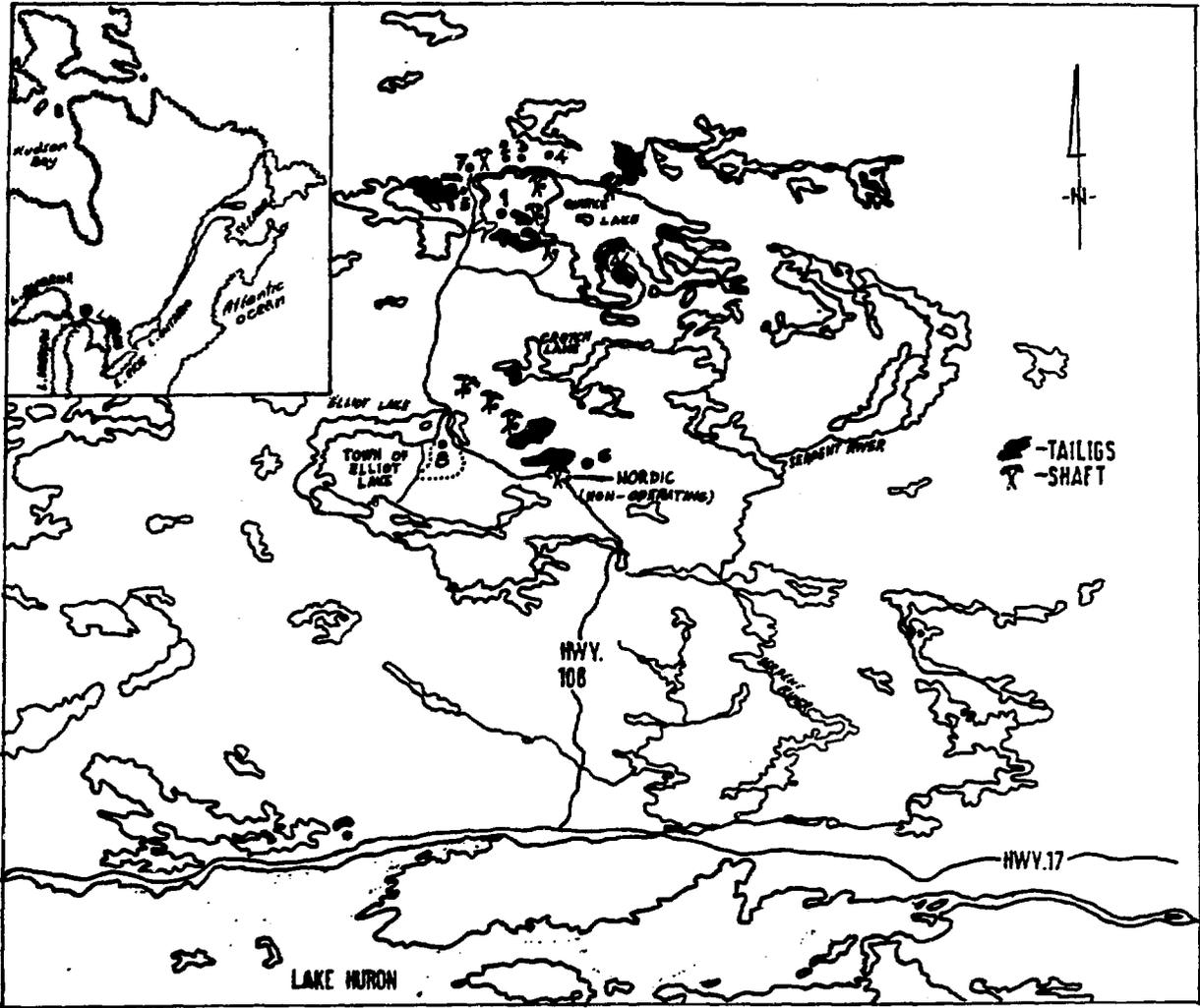


FIGURE 1 - ELLIOT LAKE AREA